

Mission Operations and Data Analysis

Meeting in Preparation for
the NASA Site Visit

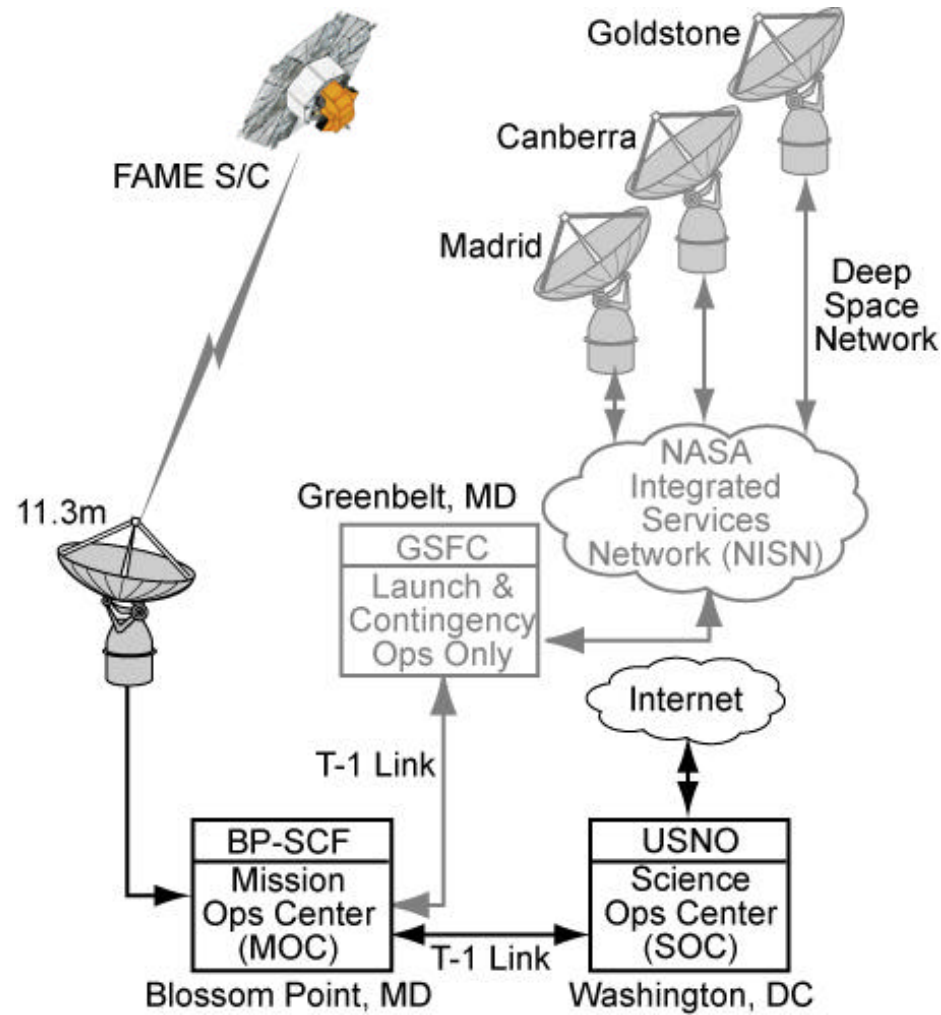
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MO&DA IPDT Lead

Introduction

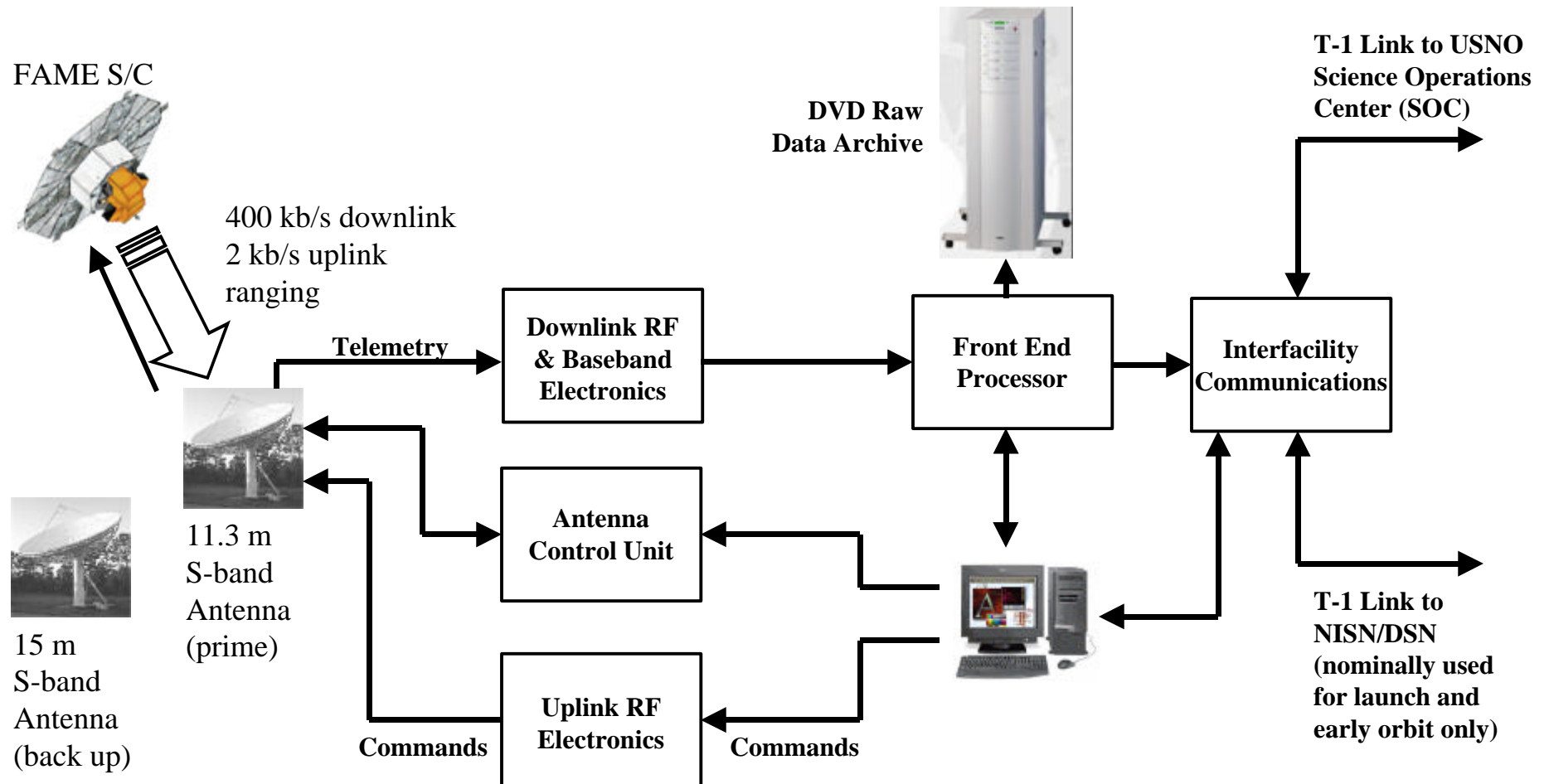
- ◆ Mission Operations Center (MOC) located at Blossom Point in southern Maryland
- ◆ Science Operations Center (SOC) located at USNO in Washington D.C.
- ◆ NISN/DSN used for launch and early orbit operations only (until FAME is in 24 hour view from BP)
- ◆ MOC and SOC are connected by a dedicated T1 link
- ◆ Raw downlink data is archived at both Blossom Point and USNO

Ground Station Concept



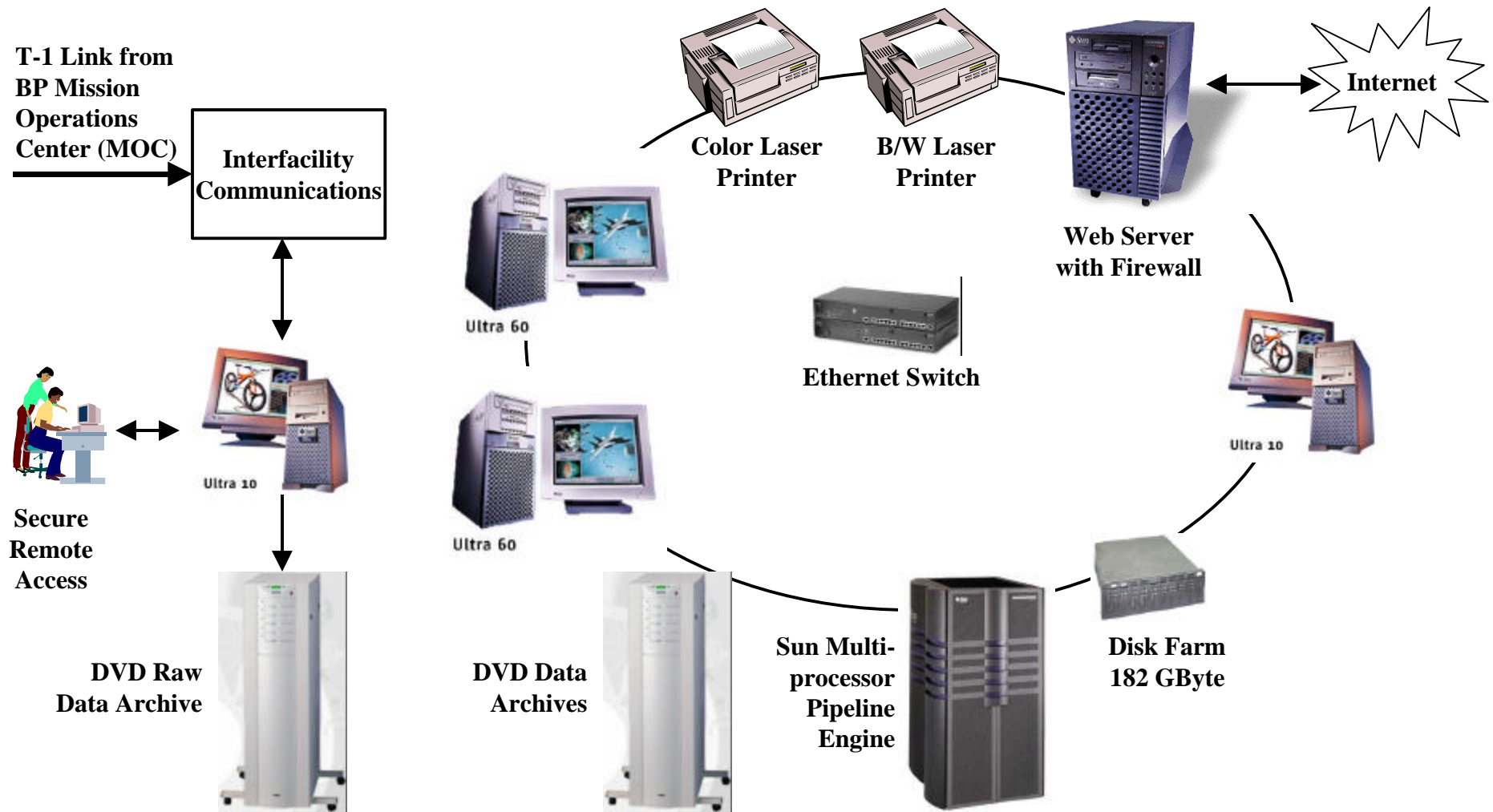
Blossom Point Ground Station

Mission Operations Center (MOC)



U.S. Naval Observatory

Science Operations Center (SOC)



Data Archives

- ◆ Raw data archive (400 kb/s for 5 years = 8 TBytes)
- ◆ Centroid archive
- ◆ Instrumental model archive
- ◆ Spiral archive
- ◆ Photometric archive
- ◆ Astrometric parameter archive
- ◆ Final catalog archive (4×10^7 stars, 200 Bytes/star + delta position \times 1000 obs. = 10 GBytes)

DVD technology

- ◆ DVD jukeboxes are now coming available
- ◆ 1.3 TByte unit with 8 drives costs under \$35k and is only 25×25×50"
- ◆ Individual disks currently 2.6 - 5.2 GBytes but should increase
- ◆ Should be more durable and reliable than magnetic media
- ◆ Current disk cost \$30 per unit, but should decrease rapidly

Budget Assumptions

- ◆ Funding start 1 October 1999
- ◆ Launch in July 2003
- ◆ 30 month NASA funded S/C operations (end January 2006)
- ◆ Catalog issued one year after end of S/C operations (January 2007)
- ◆ All dollar amounts are in FY98 dollars
- ◆ Existing hardware at BP is utilized and is costed in NRL overhead

MOC Labor

(WBS 2.1, 2.2, 2.4, 8.2, 8.4, 8.5, & 8.7)

Percentage of time allocated	Grade	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	TOTAL
Labor										
Support Engineer	GS-12	0.500	0.500	0.500	0.375					1.875
System Engineer	GS-15	0.250	0.250	0.250	0.250					1.000
Electrical Engineer	GS-12	0.500	0.500	0.500	0.625	0.500	0.500	0.125		3.250
Orbits/Trajectory Spec.	GS-12	0.250	0.250	0.250	0.875	0.625	0.500	0.125		2.875
Total		1.500	1.500	1.500	2.125	1.125	1.000	0.250		9.000

MOC Budget

(WBS 2.1, 2.2, 2.4, 8.2, 8.4, 8.5, & 8.7)

Element of Cost	Grade	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	TOTAL
Labor										
Support Engineer	GS-12	\$68,040	\$68,040	\$68,040	\$51,030					\$255,150
System Engineer	GS-15	\$47,502	\$46,980	\$46,980	\$47,502					\$188,964
Electrical Engineer	GS-12	\$68,040	\$68,040	\$68,040	\$85,050	\$68,040	\$68,040	\$17,010		\$442,260
Orbits/Trajectory Spec.	GS-12	\$34,096	\$34,020	\$34,020	\$119,070	\$85,050	\$68,040	\$17,010		\$391,306
Subcontracts										
Spacecraft Analyst					\$21,676	\$86,705	\$86,705	\$21,676		\$216,762
Comp. Operator					\$13,247	\$52,987	\$52,987	\$13,247		\$132,468
H/W Maintenance					\$19,268	\$77,071	\$77,071	\$19,268		\$192,678
S/W Maintenance					\$24,085	\$96,339	\$96,339	\$24,085		\$240,848
Materials and Equipment										
Antenna			\$337,187							\$337,187
Transmitter			\$192,678							\$192,678
T1 Hardware				\$2,890						\$2,890
OS/Comet Server				\$48,170						\$48,170
DVD Jukebox				\$34,000						\$34,000
Sun Workstations (2)				\$34,682						\$34,682
Command Encoder Units (2)				\$57,803						\$57,803
ATM Upgrade Hardware				\$31,792						\$31,792
Misc. RF Hardware				\$69,364						\$69,364
Misc. Comp. Hardware				\$33,719						\$33,719
Cabling				\$14,451						\$14,451
Supplies		\$10,646	\$915	\$19,220	\$687	\$578	\$578	\$145		\$32,769
Antenna Pad Upgrades				\$28,902						\$28,902
NISN Interface Equip.				\$28,902						\$28,902
Viterbi Bit Syncs. (2)				\$28,902						\$28,902
DSN SPPT					\$229,000					\$229,000
Comm. Line BP-GSFC					\$9,248					\$9,248
T1 Comm. Line BP-USNO					\$9,297	\$8,671	\$8,671	\$2,168		\$28,807
H/W Upgrade					\$48,170					\$48,170
Travel		\$7,708	\$7,708	\$7,708	\$11,561					\$34,685
Training		\$3,854	\$1,927							\$5,781
TOTAL		\$239,886	\$757,495	\$657,585	\$688,891	\$475,441	\$458,431	\$114,609	\$0	\$3,392,338

SOC Labor

(WBS 2.1, 2.3, 3.2, 3.3, 8.1, & 8.3)

Element of Cost	Grade	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	TOTAL
Labor										
MO&DA Lead	GS-14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.25
SOC Manager	GS-14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.25
DB Manager	GS-14	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.00
Programmer	GS-13	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.00
Programmer	GS-13	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.00
Programmer	GS-13	0.25	1.00	1.00	0.75					3.00
Data Tech.	GS-09	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.00
Data Tech.	GS-09				0.25	1.00	1.00	1.00	0.25	3.50
Data Tech.	GS-09				0.25	1.00	1.00	1.00	0.25	3.50
Post Doc	CS-11				0.25	1.00	1.00	1.00	0.25	3.50
Post Doc	CS-11				0.25	1.00	1.00	1.00	0.25	3.50
Post Doc	CS-11				0.25	1.00	1.00	1.00	0.25	3.50
Astronomer (SAO)	GS-15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.25
Physicist (SAO)	GS-14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.25
Physicist (SAO)	GS-13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.25	7.25
Physicist (SAO)	GS-13	1.00	1.00	1.00	0.75					3.75
Total		9.25	11.00	11.00	11.75	14.00	14.00	14.00	3.50	88.50

SOC Budget

Element of Cost	Grade	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	TOTAL
Labor										
MO&DA Lead	GS-14	\$119,930	\$119,930	\$119,930	\$119,930	\$119,930	\$119,930	\$119,930	\$29,982	\$869,490
SOC Manager	GS-14	\$103,447	\$103,446	\$103,446	\$103,447	\$103,466	\$103,466	\$103,466	\$25,862	\$750,046
DB Manager	GS-14	\$77,585	\$103,446	\$103,446	\$103,447	\$103,466	\$103,466	\$103,466	\$25,862	\$724,184
Programmer	GS-13	\$65,637	\$87,516	\$87,516	\$87,516	\$87,516	\$87,516	\$87,516	\$21,879	\$612,612
Programmer	GS-13	\$65,637	\$87,516	\$87,516	\$87,516	\$87,516	\$87,516	\$87,516	\$21,879	\$612,612
Programmer	GS-13	\$21,879	\$87,516	\$87,516	\$65,637					\$262,548
Data Tech.	GS-09	\$38,084	\$50,778	\$50,778	\$50,779	\$50,778	\$50,778	\$50,778	\$12,695	\$355,448
Data Tech.	GS-09				\$12,695	\$50,778	\$50,778	\$50,778	\$12,695	\$177,724
Data Tech.	GS-09				\$12,695	\$50,778	\$50,778	\$50,778	\$12,695	\$177,724
Post Doc	CS-11				\$17,271	\$69,084	\$69,084	\$69,084	\$17,271	\$241,794
Post Doc	CS-11				\$17,271	\$69,084	\$69,084	\$69,084	\$17,271	\$241,794
Post Doc	CS-11				\$17,271	\$69,084	\$69,084	\$69,084	\$17,271	\$241,794
Astronomer (SAO)	GS-15	\$136,890	\$136,890	\$136,890	\$136,891	\$136,890	\$136,890	\$136,890	\$34,223	\$992,454
Physicist (SAO)	GS-14	\$116,388	\$116,388	\$116,388	\$116,388	\$116,388	\$116,388	\$116,388	\$29,097	\$843,813
Physicist (SAO)	GS-13	\$98,460	\$98,460	\$98,460	\$98,460	\$98,460	\$98,460	\$98,460	\$24,615	\$713,835
Physicist (SAO)	GS-13	\$98,460	\$98,460	\$98,460	\$73,845					\$369,225
Subcontracts										
Materials and Equipment										
DVD Jukebox				\$34,000						\$34,000
Media				\$15,000	\$15,000	\$15,000	\$15,000			\$60,000
Ultra 10 (level 1 processor)				\$10,000						\$10,000
Color Laserprinter		\$2,500								\$2,500
B/W Laserprinter		\$1,000								\$1,000
DVD Jukebox				\$17,000						\$17,000
Ultra 60 (S/W Enineering)		\$25,000								\$25,000
Ultra 60 (S/W Enineering)		\$25,000								\$25,000
Ultra 60 (S/W Enineering)					\$25,000					\$25,000
Ultra 60 (S/W Enineering)					\$25,000					\$25,000
Ultra 10 (web site development)				\$10,000						\$10,000
Ultra 10		\$10,000								\$10,000
Ultra 10			\$10,000							\$10,000
Starfire (Pipeline Engine)				\$100,000						\$100,000
Disk Farm				\$36,000						\$36,000
Web Server		\$30,000								\$30,000
IDL		\$16,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$3,000	\$37,000
Sun Workshop (SDE/Config. Control)		\$13,000								\$13,000
DB Software				\$100,000						\$100,000
Documentation									\$10,000	\$10,000
Supplies		\$3,964	\$964	\$963	\$964	\$963	\$963	\$963	\$241	\$9,985
Travel		\$24,085	\$24,084	\$24,085	\$24,085	\$24,085	\$24,085	\$24,085	\$6,021	\$174,615
Training										
TOTAL		\$1,092,946	\$1,128,394	\$1,440,394	\$1,214,108	\$1,256,266	\$1,256,266	\$1,241,266	\$322,559	\$8,952,197

USNO Data First Look

- ◆ Raw data at BP and USNO will be archived to DVD
- ◆ First look station will be responsible for confirming that the two archives are identical, and that the data on them is valid
- ◆ One copy of the archive will be stored at the SOC, the second copy will be stored in a separate building at USNO or at an alternate location
- ◆ USNO will receive all telemetry from FAME - S/C and instrument housekeeping will be monitored by the SOC as well as the MOC

Centroiding

- ◆ Initially: Use *a priori* PSFs
- ◆ Using accumulating observations: Solve for PSFs and centroids simultaneously
- ◆ For this technique:
 - Each PSF is composed of a weighted sum of several monochromatic PSFs
 - Weights are determined by the fit
 - Constrained by photometric observations and known spectral energy distribution

Spiral Reductions

- ◆ Three methods are currently being tested for accuracy and robustness. Additional simulations are being performed to select the best procedure
 - 1) Use the four observations per rotation of each set of stars to characterize the motion of the S/C
 - 2) Use (almost) simultaneous observations of different stars to get angular separation; S/C rotation determined independently
 - 3) Use *a priori* positions and several rotations to model the motion of the S/C

Sphere reconstruction and astrometric parameter determination

- ◆ Use subset of stars and spiral solutions to globally tie spirals together
- ◆ Combine observations for each star (one at a time)
- ◆ Compute position, proper motion, parallax, and possible non-linear motion
- ◆ Identify suspected non-single stars for further processing

Improvements by iteration

- ◆ As the Mission progresses, knowledge of the S/C and individual stars improves. A re-analysis of the data is required
 - Knowledge of color-dependent PSFs improves
 - Photometric knowledge on each star increases
 - Knowledge of CCD characteristics improves
 - Identification of multiples is made

Global Alignment

- ◆ Internally, FAME will result in the most precise optical reference frame yet obtained, however, that frame must be oriented to the ICRF

To align the axes:

ICRF Directly

- FAME will observe all of the ICRF sources within its magnitude limits (approximately 35 targets)
- The FAME reference frame is then rotated to match the ICRF axes
- We may want a variety of methods and observing techniques to obtain the best solution

Global Alignment (cont.)

ICRF Indirectly

- **FAME will observe stars with “radio” emission**
- **VLBA observations will be made of “radio” stars**
- **Obtain observations of 20–30 stars at a minimum of two epochs with VLBA**
- **The FAME reference frame is then rotated to match the ICRF axes**
- **We may want a variety of methods and observing techniques to obtain the best solution**

⇒ Use a weighted solution for alignment

Photometric Pipeline Overview

- ◆ We can obtain photometric observations from both the astrometric and the photometric CCDs
- ◆ 24 CCDs, each having 2 amplifiers with 3 gain settings
- ◆ Photometric CCD will use the Sloan Digital Sky Survey filter set (g' , r' , i' , z')
- ◆ Each star will be observed:
 - approx. 950 times with the astrometric CCDs
 - approx. 35 times with the photometric CCDs
- ◆ Transform from internal system to SDSS system via standards in the SDSS field
- ◆ Provide constraints on the PSF

Photometric Pipeline Approach

- ◆ **Characterize the instrument**
 - **Generate bias and flat field data for each CCD**
 - **Characterize bias and gain values for each of the gain stages used for each of the 48 signal chains**
 - **Select primary and secondary calibrators**
- ◆ **Generation of intermediate standards**
 - **Dominated by photon statistics**
 - **Each tested for variability**
 - **Choose an adequate number to identify changes in CCD calibrations**
 - **Can be use to transform to a standard system**

Photometric Pipeline Approach (cont.)

- ◆ Establish internal photometric system
 - Solve for calibration parameters
 - Solve for mean flux of constant stars
- ◆ Feedback to astrometric pipeline
 - Constrain PSFs
 - Improve centroiding models
- ◆ Transform to SDSS system using stars in the SDSS field

Data Presentation to the Public

- ◆ Final catalog archive and data analysis pipeline documentation will be available via the internet
- ◆ Data will be presented in a modern and usable format, presumably Astro-XML
- ◆ Final data catalog shall also be delivered to NASA on DVDs